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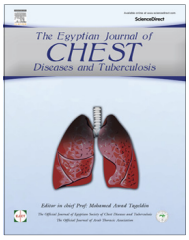

ORIGINAL ARTICLE

# Predictive value of different scoring systems for critically ill patients with hospital acquired pneumonia

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**KEYWORDS**

SMART-COP;
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ATS

**Abstract** *Introduction:* Hospital-acquired pneumonia (HAP) and ventilator-associated pneumonia (VAP) are important causes of morbidity and mortality despite improved antimicrobial therapy, supportive care, and prevention. General risk factors for developing HAP include age older than 70 years, serious comorbidities, malnutrition, impaired consciousness, prolonged hospitalization and COPD. The availability of valid criteria for defining severe pneumonia would provide a more reliable basis for improving patients risk assessment. The aim of this study was to assess the prognostic value of 7 different scores: Pneumonia Severity Index (PSI), CURB 65, Modified ATS rule, infectious Diseases Society of America/American Thoracic Society Consensus Guidelines (IDSA/ATS), SMART COP, Simplified SMART-COP (SMART CO) and SOAR) in assessing the severity of HAP and outcome of patients.

*Methods:* This is a prospective Cohort study performed on a sixty patients admitted to critical care medicine department of Alexandria University Hospital in Egypt over 12 months. All patients were diagnosed as HAP. Calculation of the mentioned 7 scores was done once diagnosis of HAP was confirmed.

*Results:* The Area Under the Curve was highest in SMART-cop (AUC = 0.820) followed by the SMART-CO score (AUC := 0.807) and PSI score (AUC := 0.806). All the previous scores SMART-cop score at Cutoff value $\geqslant$ 2, SMRT-Co Score at Cutoff value $\geqslant$ 2, Modified ATS score at Cutoff value $\geqslant$ 0.5 and PSI (pneumonia severity index) at Cutoff value $\geqslant$ 3,. have the highest sensitivity (sensitivity 100% for each) in predicting 28-day mortality, regarding Specificity, SMART-cop score is the most specific one (Specificity = 93%) in predicting 28-day mortality followed by Modified ATS score (Specificity = 90%). Regarding the duration of Mechanical Ventilation, it was found that SMART-cop ($R$ = 0.824, $p$ = 0.0001) followed by IDSA/ATS scores

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($R = 0.787$, $p = 0.0001$) had the highest correlation in predicting duration of Mechanical Ventilation in critically ill patient with VAP as a higher SMART-cop and IDSA/ATS score reflect that the pneumonia was complicated with septic shock and respiratory failure.

*Conclusions:* SMART – cop score is the most sensitive score in predicting 28-day mortality in the studied patient followed by SMART – co and PSI score). SMART-cop score is the most specific one (Specificity = 93%) in followed by Modified ATS score (Specificity = 90%).



## Introduction

Hospital-acquired (or nosocomial) pneumonia (HAP) is pneumonia that occurs 48 h or more after admission and did not appear to be incubating at the time of admission. Ventilator-associated pneumonia (VAP) is a type of HAP that develops more than 48 hours after endotracheal intubation as defined by The 2005 American Thoracic Society/Infectious Diseases Society of America (ATS/IDSA) [1].

HAP is the leading cause of death among hospital-acquired infections, with estimates of HAP-associated mortality ranging from 20% to 50%. While some studies indicate an attributable mortality of 33%, another suggests that pneumonia is not a significant risk factor for death after adjusting for other predictors of mortality. The highest risk for HAP is in patients on mechanical ventilation (ie, VAP), in whom the entity has been best studied [2,3].

There are many Risk factors for HAP which include [male sex, coma, COPD (chronic obstructive pulmonary disease), bronchoscopy, tracheostomy, use of antacids, serious disease predating the onset of VAP, infection at other sites and duration of prior antibiotic use >4 days] [4].

Severity assessment of pneumonia is considered the key to deciding the site of care and guiding both general management and antibiotic treatment. Much contemporary research has been directed toward the development of evidence-based measures of illness severity in community-acquired pneumonia (CAP) by relating a number of clinical and laboratory features to significant outcomes, namely mortality [5].

The clinical pulmonary infection score (CPIS) has been investigated in multiple trials but the evidence to date does not support widespread use of the CPIS as a diagnostic, prognostic, or therapeutic decision tool, because it is not an adequate surrogate for the diagnosis of VAP. Its poor sensitivity and specificity in most studies preclude its use as an accurate noninvasive diagnostic device. Of all the components of the CPIS, the measure of oxygenation provides the most information as a time-dependent factor during early VAP for predicting its outcome in response to treatment, and deriving a complex score appears to be superfluous for this purpose [6].

Although the severity of HAP and its effect on the outcome of critically ill patients is much more serious than CAP, yet no formal scoring system – to my knowledge – has been created or validated to stratify HAP which is really needed to tailor the medical care and pick up more serious cases to be subjected to more intensive therapy and care. Considering the overall similar pathology in both categories of pneumonia (CAP & VAP), the idea was to try the application of different scoring systems designed mainly for CAP for risk stratification of VAP and check its validity for this purpose. The idea has been raised in a single retrospective study published in 2011 by a Chinese group who concluded that the CAP scores can be also applied for HAP but they didn't focus too much on the validity of the each single score compared to others [7].

The aim of this study was to assess the prognostic value of different scores including (PSI, CURB65, SMART COP, SMART CO, MODIFIED ATS, IDSA/ATS and SOAR) in patients with hospital acquired pneumonia in predicting 28 day mortality, days on mechanical ventilation and ICU length of stay.

## Patients and methods

This study had been conducted on 60 patients admitted to Alexandria University Hospital Critical Care Medicine Department in Egypt who developed hospital acquired pneumonia including ventilator associated pneumonia after approval of the local ethics committee of the faculty of medicine, Alexandria University. All patients met the criteria of developing pneumonia after 48 h of admission and they had new or progressive infiltrates on the chest X-ray with one of the 3 requirements of: fever more than 37.8 °C or purulent

**Table 1** Area Under the Curve.

| Test result variable(s) | Area | Std. error (a) | Asymptotic sig. (b) | Asymptotic 95% confidence interval | |
|---|---|---|---|---|---|
| | | | | Lower bound | Upper bound |
| PSI (pneumonia severity index) | 0.806 | 0.058 | 0.000 | 0.691 | 0.920 |
| CurB-65 | 0.747 | 0.067 | 0.001 | 0.616 | 0.878 |
| Modified ATS | 0.772 | 0.061 | 0.000 | 0.651 | 0.892 |
| IDSA/ATS | 0.790 | 0.061 | 0.000 | 0.670 | 0.910 |
| SOAR | 0.734 | 0.066 | 0.002 | 0.605 | 0.863 |
| SMART-cop | 0.820 | 0.054 | 0.000 | 0.714 | 0.926 |
| SMRT-Co Score | 0.807 | 0.057 | 0.000 | 0.695 | 0.919 |

sputum or leukocytosis. Patients less than 18 years, or having lung cancer and those who hadn't the full data for scoring fulfilled are excluded from the study.

The next 7 scores were recorded for each patient once the diagnosis of HAP was established and the correlation with the outcome parameters was performed using adequate statistical analysis. The scores used were:

**PSI (pneumonia severity index) score** [8]: The score uses demographics (whether someone is older, and is male or female), the coexistence of co-morbid illnesses, findings on physical examination and vital signs, and essential laboratory findings. Patients could be stratified into five risk categories, Risk Classes I–V, and that these classes could be used to predict 30-day survival.

**Step 1: Stratify to Risk Class I vs. Risk Classes II–V**

| | |
|---|---|
| *Presence of:* | |
| Over 50 years of age | Yes/No |
| Altered mental status | Yes/No |
| Pulse ⩾125/min | Yes/No |
| Respiratory rate >30/min | Yes/No |
| Systolic blood pressure <90 mm Hg | Yes/No |
| Temperature <35 °C or ⩾40 °C | Yes/No |
| *History of:* | |
| Neoplastic disease | Yes/No |
| Congestive heart failure | Yes/No |
| Cerebrovascular disease | Yes/No |
| Renal disease | Yes/No |
| Liver disease | Yes/No |
| If any "Yes", then proceed to Step 2 | |
| If all "No" then assign to **Risk Class I** | |

**Step 2: Stratify to Risk Class II vs. III vs. IV vs. V**

| **Demographics** | **Points assigned** |
|---|---|
| If Male | + Age (yr) |
| If Female | + Age (yr) − 10 |
| Nursing home resident | +10 |
| *Comorbidity* | |
| Neoplastic disease | +30 |
| Liver disease | +20 |
| Congestive heart failure | +10 |
| Cerebrovascular disease | +10 |
| Renal disease | +10 |
| *Physical exam findings* | |
| Altered mental status | +20 |
| Pulse ⩾125/minute | +20 |
| Respiratory rate >30/minute | +20 |
| Systolic blood pressure <90 mm Hg | +15 |
| Temperature <35°C or ⩾40°C | +10 |
| *Lab and radiographic findings* | |
| Arterial pH <7.35 | +30 |
| Blood urea nitrogen ⩾30 mg/dl (9 mmol/liter) | +20 |
| Sodium <130 mmol/liter | +20 |
| Glucose ⩾250 mg/dl (14 mmol/liter) | +10 |
| Hematocrit <30% | +10 |
| Partial pressure of arterial O2 < 60 mmHg | +10 |
| Pleural effusion | +10 |
| Arterial pH < 7.35 | +30 |
| $\sum$ <70 = **Risk Class II** | |
| $\sum$ 71–90 = **Risk Class III** | |
| $\sum$ 91–130 = **Risk Class IV** | |
| $\sum$ >130 = **Risk Class V** | |

*__CURB-65__, also known as the CURB criteria, The CURB-65 is based on the earlier CURB score and is recommended by the British Thoracic Society for the assessment of severity of pneumonia [9–11]. The score is an acronym for each of the risk factors measured. Each risk factor scores one point, for a maximum score of 5: Confusion of new onset, Urea greater than 7 mmol/l (Blood Urea Nitrogen > 19), Respiratory rate of 30 breaths per minute or greater, Blood pressure less than 90 mmHg systolic or diastolic blood pressure 60 mmHg or less and Age 65 or older [1].

*__Modified ATS rule__: This rule is met if at least 2 of 3 minor criteria assessed at admission (systolic blood pressure <90 mmHg, multilobar (>2 lobes) involvement, $PaO_2/FiO_2$ < 250), or 1 of 2 major criteria assessed at admission or during follow up (requirement for mechanical ventilation or septic shock) were present [2,3].

*__IDSA/ATS__ refers to Infectious Diseases Society of America/American Thoracic Society Consensus Guidelines on the Management of Community-Acquired Pneumonia in Adults [4]. In addition to the 2 major criteria (need for mechanical ventilation and septic shock), an expanded set of minor criteria [respiratory rate ⩾30 breaths/min; arterial oxygen pressure/fraction of inspired oxygen ($PaO_2/FiO_2$) ratio ⩽250; multilobar infiltrates; confusion; blood urea nitrogen level ⩾20 mg/dl; leucopenia resulting from infection; thrombocytopenia; hypothermia; or hypotension requiring aggressive fluid resuscitation].

*__SOAR__ comprises systolic blood pressure, oxygenation, age, and respiratory rate, severe pneumonia is then defined as the presence of ⩾ 2 out of the 4 criteria. A score of one is given for the presence of each of the following (dichotomized variables): systolic BP < 90 mmHg; $PaO_2$:$FiO_2$ < 250; age ⩾ 65 years; and RR ⩾ 30/min [9].

*__SMART-COP__ scores will be calculated as presented by Charles, and consisted of systolic blood pressure (<90 mmHg, 2 points); multilobar chest radiography involvement (1 point); low albumin level (<3.5 g/dl, 1 point); high respiratory rate (⩽50 years: ⩾25 br/min, >50 years: ⩾30 br/min; 1 point); tachycardia (⩾125 bpm; 1 point); confusion (new onset; 1 point); poor oxygenation (⩽50 years: $PaO_2$ < 70 mmHg or O2 saturation ⩽ 93%, >50 years: $PaO_2$ < 60 mmHg or O2 saturation ⩽ 90%; 2 points); and low arterial pH (<7.35; 2 points) [12].

*__SMRT-Co Score__ (Simplified SMART-COP) was designed for more simplification, and it excludes the results for albumin, arterial pH, and $PaO_2$ [12].

**Statistical Analysis**: Categorical variables were analyzed using a chi-square test or Fisher's exact test where appropriate, and continuous variables were compared using Student's *t*-test or the Mann- Whitney U test. The discriminatory power of each scoring index was measured by receiver operating characteristic (ROC) curves. The area under the ROC curve (AUC) was calculated to give an estimate of the overall accuracy of each scoring index in predicting different patient outcomes (28-days mortality). An area of 0.50 implies that the scoring index is no better than chance, whereas an area of 1 implies perfect accuracy. Sensitivity, specificity and accuracy were also calculated as well with their 95% confidence intervals for all the scoring indices. All tests were two-tailed, and P value < 0.05 was considered to be statistically significant. All

statistical analyses were performed using the SPSS 14.0 software (SPSS Inc., Chicago, IL, USA) and the MedCalc 9.6.2.0 package (MedCalc Software, Mariakerke, Belgium).

## Results

As shown in Table 1 and Fig. 1 it was found that the Area Under the Curve was highest in SMART-cop (AUC := 0.820) followed by the SMART-CO score (AUC := 0.807) and PSI score(AUC := 0.806) (it means that SMART –cop score is the most sensitive score in predicting 28 day mortality in the studied patient followed by SMART – co and PSI score). The Area Under the Curve (AUC) is a measure of the accuracy of a test. It describes the relationships between sensitivity and specificity.

As shown in Table 2 and Fig. 2 it was found that from all the previous scores SMART-cop score at Cutoff value $\geqslant 2$, SMRT-Co Score at Cutoff value $\geqslant 2$, Modified ATS score at Cutoff value $\geqslant 0.5$ and PSI (pneumonia severity index) at Cutoff value $\geqslant 3$, have the highest sensitivity (sensitivity 100% for each) in predicting 28-day mortality in the studied group of patients. Regarding Specificity it was found that SMART-cop score is the most specific one (Specificity = 93%) in predicting 28-day mortality in the studied patients followed by Modified ATS score (Specificity = 90%).

Table 3 shows the correlation between days of MV and different scores, it was found that there was a significant correlation between the scores and the duration of MV, the most highly significant correlation was found in SMART-cop ($R = 0.824$) and IDSA/ATS scores ($R = 0.787$).

Table 4, shows the correlation between duration of ICU stay and different scores, it was found that there was a significant correlation between the scores and the duration of ICU stay, the most highly significant correlation was found in SMART-cop ($R = 0.809$, $p = 0.0001$) and IDSA/ATS scores ($R = 0.809$, $p = 0.0001$) followed by SMRT-Co Score ($R = 0.806$, $p = 0.0001$) and SOAR score ($R = 0.704$, $p = 0.0001$).

## Discussion

In the present study it was observed that there was a significant correlation between the pneumonia severity index score (PSI) and mortality. The mortality rate at 28 days increased significantly as the PSI score is greater than risk class $4\ \Sigma > 90$) $p = 0.0001$), as regarding sensitivity it was observed that PSI score is sensitive in predicting mortality (AUC := 0.806) this can be explained by the fact that higher PSI scores reflect that this group of patients have one or more comorbidities rather than pneumonia including (Neoplastic disease, Liver disease, Congestive heart failure, Cerebro-vascular disease and Renal disease) and also a higher PSI score reflects that pneumonia was severe to the degree that the patient developed Systemic Inflammatory Response Syndrome (SIRS) and/or sepsis. So there was a higher risk of mortality among this group of patients. However, PSI score is complicated to use, requiring computation of a score based on 20 variables. Similar finding were reported by workers like Wen-Feng et al. they conducted a retrospective cohort study based on an inpatient database from 6 medical centers in Taiwan and they found that PSI (>90) has the highest sensitivity in predicting 28-days mortality (AUC: 0.70) among patients with Hospital acquired pneumonia (HAP) [7].

Almost Similar results can be observed in both studies with SMART-cop score which showed a sensitivity of 100% with score $\geqslant 2$ which could be explained by may parameters used

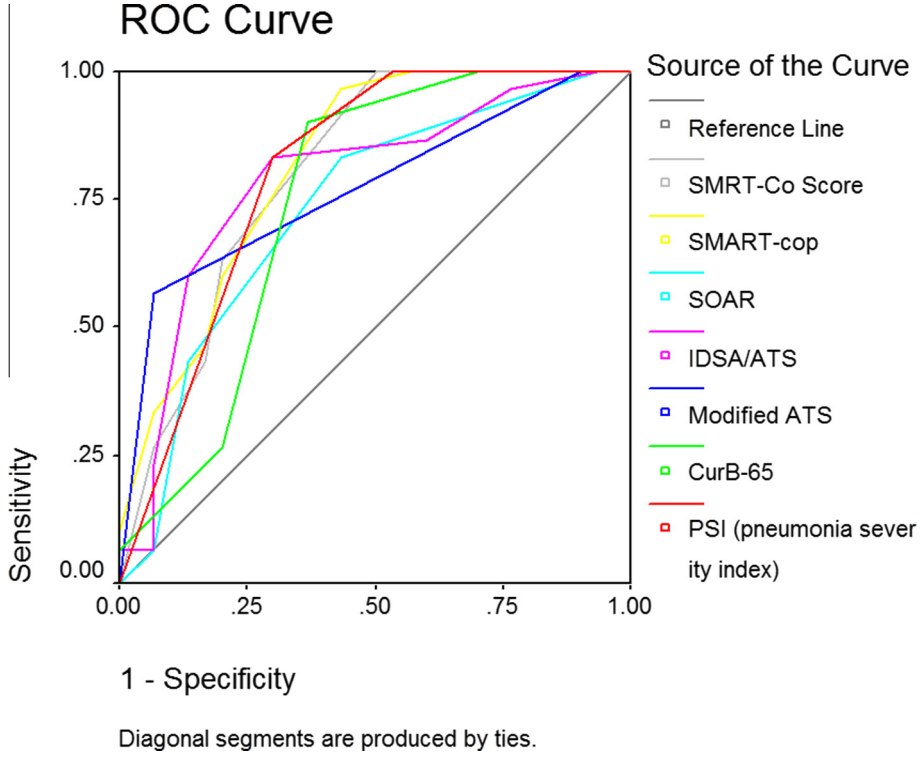


**Fig. 1** ROC Curve to determine the sensitivity and specificity of different score in relation to the outcome (28-day mortality).

**Table 2** Cutoff value of different scores and the sensitivity and specificity of each score.

| Test result variable(s) | Positive if greater than or equal to | Sensitivity | Specificity | Accuracy |
|---|---|---|---|---|
| PSI (pneumonia severity index) | 3.000 | 1.000 | 0.833 | 0.85 |
| CurB-65 | 3.000 | 0.900 | 0.367 | 0.65 |
| Modified ATS | 0.500 | 1.000 | 0.900 | 0.95 |
| IDSA/ATS | 3.000 | 0.967 | 0.767 | 0.82 |
| SOAR | 2.000 | 0.833 | 0.433 | 0.65 |
| SMART-cop | 2.000 | 1.000 | 0.933 | 0.97 |
| SMRT-Co Score | 2.000 | 1.000 | 0.500 | 0.79 |

**Table 3** Correlation between duration of MV and different scores.

| | | Days of MV |
|---|---|---|
| PSI (pneumonia severity index) | *R* | 0.301(*) |
| | *p* | 0.019 |
| CurB-65 | *R* | 0.634(**) |
| | *p* | 0.0001 |
| Modified ATS | *R* | 0.541(**) |
| | *p* | 0.0001 |
| IDSA/ATS | *R* | 0.787(**) |
| | *p* | 0.0001 |
| SOAR | *R* | 0.666(**) |
| | *p* | 0.0001 |
| SMART-cop | *R* | 0.824(**) |
| | *p* | 0.0001 |
| SMRT-Co Score | *R* | 0.741(**) |
| | *p* | 0.0001 |

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

on it (8 parameters) which keep it very sensitive compared to other scores using 4 or 5 parameters like CURB65 score which have a sensitivity of 90% or SOAR which have the lowest sensitivity of 83%. In terms of specificity SMART-cop again carries a high specificity of 97% compared to only 83% for PSI and subsequently it had also the highest accuracy by 97%.

SMART-COP Score has less popularity compared to PSI or CURB 65 [13] which are more commonly used in CAP classification, this may be related to more items to be fulfilled in SMART-cop but considering that we are dealing here with HAP. The provision of the required data is not that difficult and mostly will be done as a routine part from the work up of any case of HAP.

The same superiority of SMART- COP in the present study on HAP had been validated in CAP studies as shown in another study carried out on 335 patients with Community-Acquired Pneumonia (CAP) it was found that SMART-COP score was superior to the other prognostic scoring tools for predicting need for Intensive Respiratory or Vasopressor

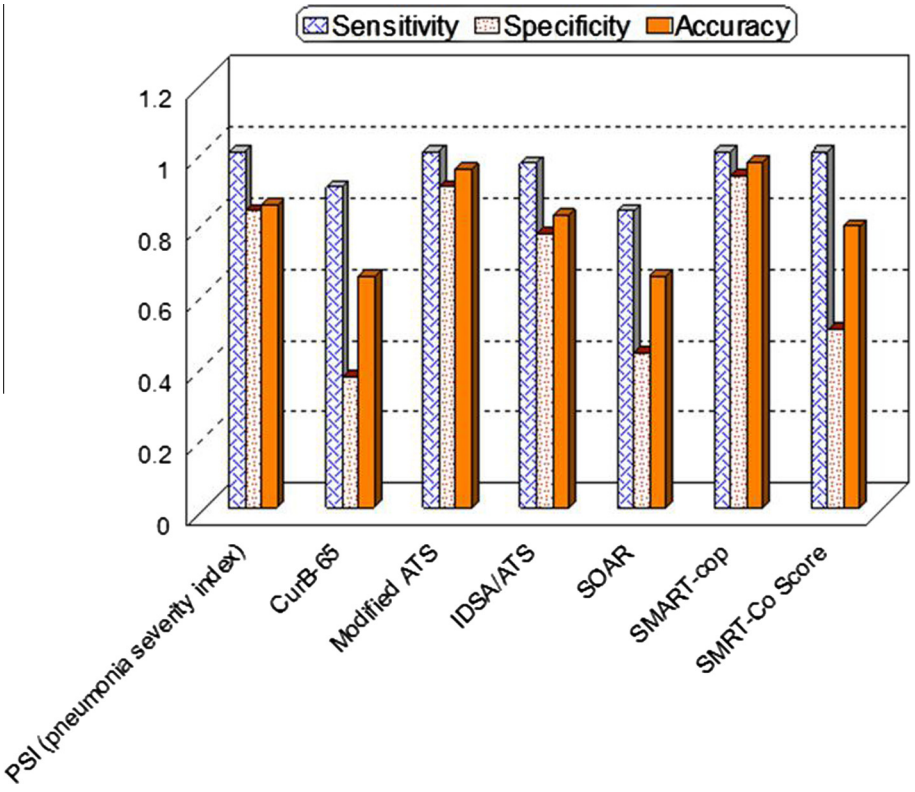


**Fig. 2** The sensitivity and specificity of each score.

**Table 4** Correlation between duration of ICU stay and different scores.

| | | Duration of ICU |
|---|---|---|
| PSI (pneumonia severity index) | *R* | 0.284(*) |
| | *p* | 0.028 |
| CurB-65 | *R* | 0.655(**) |
| | *p* | 0.0001 |
| Modified ATS | *R* | 0.555(**) |
| | *p* | 0.0001 |
| IDSA/ATS | *R* | 0.809(**) |
| | *p* | 0.0001 |
| SOAR | *R* | 0.704(**) |
| | *p* | 0.0001 |
| SMART-cop | *R* | 0.809(**) |
| | *p* | 0.0001 |
| SMRT-Co Score | *R* | 0.806(**) |
| | *p* | 0.0001 |

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Support (IRVS) rather than mortality, with a sensitivity of 85%, compared with 55% for a CURB-65 $\geqslant 3$ or a PSI $\geqslant$ class 4 [14]. Similar findings were reported by workers like Brando-Neto et al., who conducted a prospective cohort study on 53 H1N1 pneumonia patients. It was found that the SMART-COP score was a better tool for screening in-hospital case fatality compared with the Simple Triage Scoring System (STSS) in patients with H1N1 pneumonia. The SMART-COP had higher sensibility and negative predictive values with consequently better accuracy than the STSS (92% versus 71.4%, 90.4% versus 85.7%, and 83% versus 68%, respectively) [2].

Surprisingly, the ATS rule scoring system which was initially designed to decide need for ICU admission for CAP patients carries also a very high sensitivity of 100%, specificity of 90% and accuracy of 95%. Considering the simplicity of calculation of this score with minimal number of items needed, it should be considered also as a good option for classifying HAP and predicting mortality.

All the studied scores except for PSI score showed a significant correlation with both the duration of mechanical ventilation and duration of ICU stay while PSI score showed less correlation with the duration of mechanical ventilation and the duration of ICU stay. There is no clear explanation why the PSI was not able to predict those 2 parameters like other scores although a lot of points which can predict the severity of illness and the probable long term stay on the ventilator and subsequently in the ICU are included in that score. In the present study it was observed that SMART-cop score ($R = 0.809$) and IDSA/ATS score ($R = 0.809$) had the highest correlation in predicting duration of ICU stay in critically ill patients with HAP followed by SMRT-Co Score ($R = 0.806$) and SOAR ($R = 0.704$). This was in agreement with the study designed by Kuang-Yao Yang et al., it was observed that SMART-COP (AUC: 0.84, 0.82), Modified ATS (AUC: 0.84, 0.82) and IDSA/ATS (AUC: 0.80, 0.79) performed better (statistically significant difference) than PSI, CURB-65, SOAR and SMRT-CO. in predicting need for ICU admission and duration of ICU stay [7]. This again denotes the superiority of SMART-COP as proved by both results to be the best score in this point.

The general conclusion that almost all of the scores used for CAP assessment could be also very valuable for HAP. Most of the scores are sharing many points in common with some differences, The SMART-COP showed higher performance in all the studied outcome parameters compared to other scores. The simplified form of SMART-COP which is SMRT-CO with exclusion of 3 parameters (albumin, arterial pH, and $PaO_2$) did not show the same power which highlights the crucial importance of those 3 parameters which might improve the accuracy of other scores if also it is included there). However further studies are still needed to validate the use of SMART-COP regularly in the risk stratification of patients with HAP and VAP.

Limitations of the present study are related to its design. As we only considered patients admitted to ICU, we may have missed another category of patients that were diagnosed with pneumonia while hospitalized in the ward for more than 48 h, as well as patients directly transferred from chronic healthcare facilities to internal medicine wards which definitely represent less sick patients with certainly lower scores. The other limitation of the study is that we used the duration of mechanical ventilation which is an accepted parameter used in most of the similar studies while using 28 days ventilator free survival might be more accurate.

## Conflict of interest

All Authors are declaring that they do not have conflict of interest related to this study.

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